SECTION 4 SLUDGE TREATMENT AND DISPOSAL COSTS

4.1 Plate and Frame Pressure Filtration - Sludge Stream

Pressure filtration systems are used for the removal of solids from waste streams. This section details *sludge stream* filtration which is used to treat the solids removed by the clarifiers in the Metals Options.

The pressure filtration system costed by EPA for sludge stream filtration consists of a plate and frame filtration system. The components of the plate and frame filtration system include: filter plates, filter cloth, hydraulic pumps, pneumatic booster pumps, control panel, connector pipes, and a support platform. For design purposes, EPA assumed the sludge stream to consist of 80 percent liquid and 20 percent (200,000 mg/l) solids. EPA additionally assumed the sludge stream to be 20 percent of the total volume of wastewater treated. EPA based these design parameters on CWT Questionnaire 105.

In costing for sludge stream treatment, if a facility does not have sludge filtration systems in-place, EPA estimated capital costs to add a plate and frame pressure filtration system to their on-site treatment train[1]. If a facility's's treatment train includes more than one clarification step in its treatment train (such as for Metals Option 3), EPA only costed the facility for a single plate and frame filtration system. EPA assumed one plate and frame filtration system could be used to process the sludge from multiple clarifiers. Likewise, if a facility already had a sludge filtration system in-place, EPA assumed that the in-place system would be sufficient and did not estimate any sludge filtration capital costs for these facilities.

[1] If a facility only had to be costed for a plate and frame pressure filtration system to process the sludge produced during the tertiary chemical precipitation and clarifications steps of metals Option 3, EPA did not cost the facility for a plate and frame pressure filtration system. Likewise, EPA assumed no O&M costs associated with the treatment of sludge from the tertiary chemical precipitation and clarification steps in Metals Option 3. EPA assumed that the total suspended solids concentration at this point is so low that sludge stream filtration is unnecessary.

Capital and Land Costs

EPA developed the capital cost equation for plate and frame sludge filtration by adding installation, engineering, and contingency costs to vendors' equipment cost estimates. EPA used the same capital cost equation for the plate and frame sludge filtration system for all of the Metals Options.

Table 4-1 presents the itemized total capital cost estimates for the plate and frame sludge filtration systems for all the Metals Options. The resulting cost curve is presented as Figure 4-1. The sludge filtration total capital cost equation for all the Metals Options is:

$$\mathbf{\ln(Y1) = 14.827 + 1.087\ln(X) + 0.0050(\ln(X))^2} \qquad \mathbf{(4\text{-}1)}$$

where:

X = Flow (MGD) of Liquid Stream and

Y1 = Capital Cost (1989 $).

Table 4-1. Total Capital Cost Estimates for Plate and Frame Pressure Filtration (Sludge Stream)

Wastewater Influent Flow (MGD)	Average Vendor Equipment Cost	Install. Cost	Total Capital & Installation Cost	Engineering & Contingency Fee	Total Capital Cost (1989 $)
0.000001	6,325	2,214	8,539	2,562	10,102
0.00001	6,325	2,214	8,539	2,562	10,102
0.0001	6,482	2,269	8,751	2,625	10,352
0.001	9,897	3,464	13,361	4,008	15,806
0.01	29,474	10,316	39,790	11,937	47,072
0.05	93,960	32,886	126,846	38,054	150,059
0.10	171,183	59,914	231,097	69,329	273,388
0.50	870,475	304,666	1,175,141	352,542	1,390,192
1.00	1,939,145	678,701	2,617,846	785,354	3,096,912

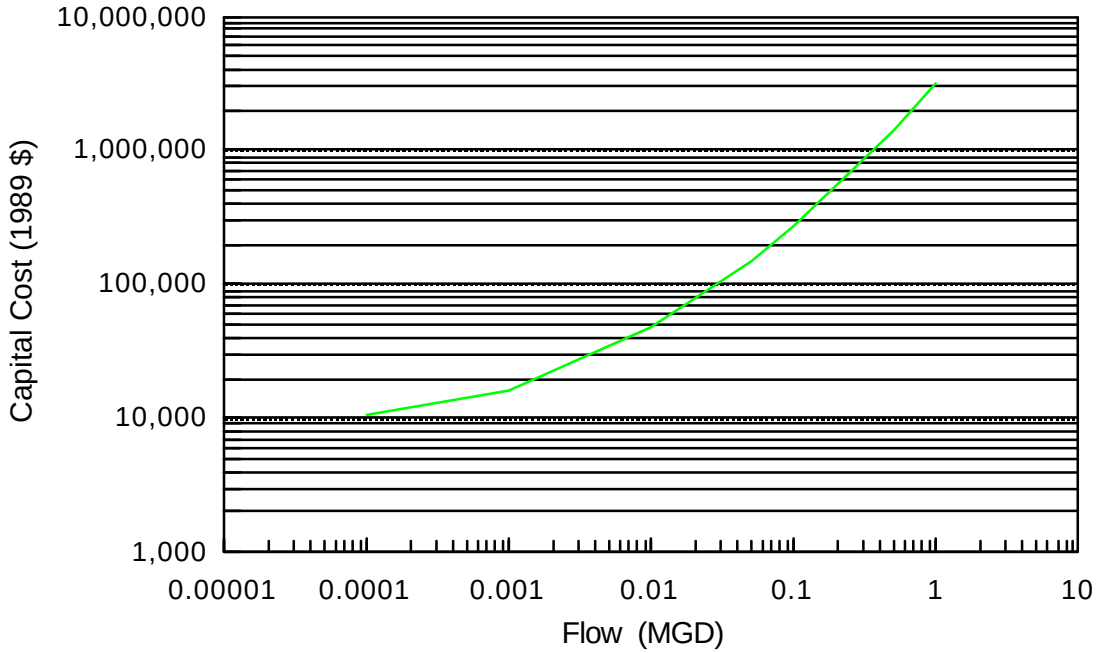

Figure 4-1. Plate and Frame Filtration (Sludge Stream) Total Capital Cost Curve - All Metals Options

EPA calculated land requirements for the plate and frame pressure filtration systems using the system dimensions plus a 20-foot perimeter. The land requirement curve is presented as Figure 4-2. The land requirement equation for all Metals Options sludge filtration is the same and is:

$$\ln(Y3) = -1.971 + 0.281\ln(X) + 0.018(\ln(X))^2 \quad \textbf{(4-2)}$$

where:

X = Flow Rate (MGD) of Liquid Stream and

Y3 = Land Requirement (Acres).

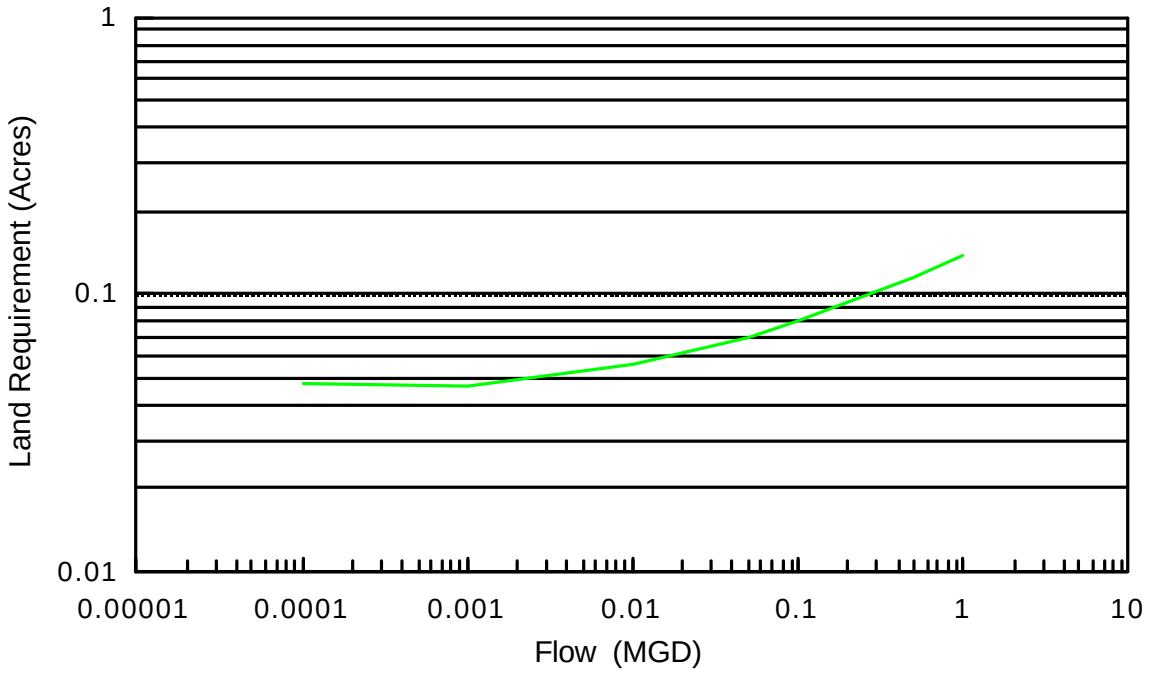

Figure 4-2. Plate and Frame Filtration (Sludge Stream) Land Requirement Curve - All Metals Options

Operation and Maintenance Costs Metals Options 2 and 3

The operation and maintenance costs for Metals Options 2 and 3 plate and frame sludge filtration consist of labor, electricity, maintenance, and taxes and insurance. EPA approximated the labor requirements for the plate and frame sludge filtration system to be thirty minutes per batch based on the Metals Options 2 and 3 model facility. Because no chemicals are used with the plate and frame sludge filtration units, EPA did not include costs for chemicals. EPA estimated electricity, maintenance, and taxes and insurance using the factors listed in Table 1-2.

Table 4-2 presents the itemized O&M cost estimates for the plate and frame sludge filtration systems for Metals Options 2 and 3. The resulting cost curve is presented as Figure 4-3. The O&M cost equation for the Metals Options 2 and 3 sludge filtration systems is:

$$\mathbf{ln(Y2) = 12.239 + 0.388ln(X) + 0.016(ln(X))^2} \quad \textbf{(4-3)}$$

where:

X = Flow Rate (MGD) of Liquid Stream and

Y2 = O&M Cost (1989 $/YR).

Table 4-2. O&M Cost Estimates for Plate and Frame Pressure Filtration - Metals Options 2 and 3 (Sludge Stream - Excluding Filter Cake Disposal Costs)

Wastewater Influent Flow (MGD)	Energy	Maintenance	Taxes & Insurance	Labor	O&M Cost (1989 $/YR)
0.000001	1,000	404	202	17,730	19,336
0.00001	1,000	404	202	17,730	19,336
0.0001	1,001	414	207	17,730	19,352
0.001	1,005	632	316	35,457	37,410
0.01	1,010	1,882	941	53,549	57,382
0.10	1,104	10,935	5,468	53,549	71,056
0.50	1,520	55,607	27,804	62,504	147,435
1.0	2,040	123,876	61,938	71,550	259,404

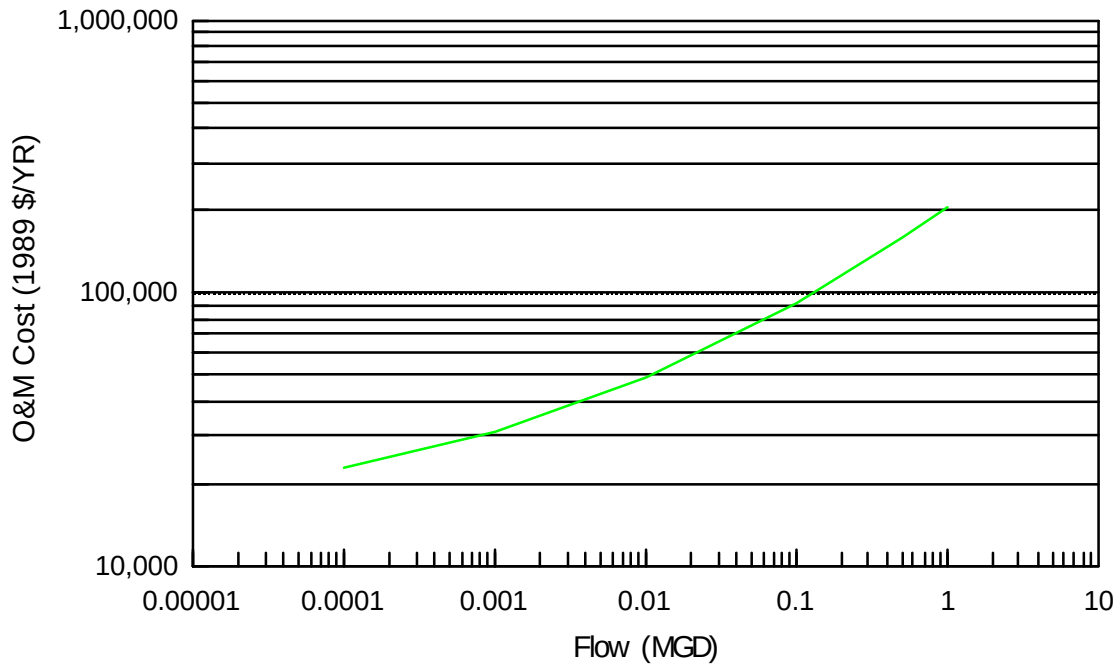

Figure 4-3. Plate and Frame Filtration (Sludge Stream) O&M Cost Curve - Metals Options 2 and 3

For facilities which already have a sludge filtration system in-place, EPA included plate and frame filtration O&M upgrade costs. Since the sludge generated from the secondary precipitation and clarification steps in Metals Options 2 and 3 is the sludge which requires treatment for these options, these facilities would be required to improve pollutant removals from their secondary precipitation current performance concentrations to the long term averages for Metals Options 2 and 3. Therefore, EPA calculated the percent difference between secondary precipitation current performance and the Metals Options 2 and 3 long-term averages. EPA determined this percentage to be an increase of three percent.

As such, for facilities which currently have sludge filtration systems in place, for Metals Options 2 and 3, EPA included an O&M upgrade cost which is three percent of the O&M costs of a new system (except for taxes and insurance, which are a function of the capital cost).

Table 4-3 presents the itemized O&M upgrade cost estimates for the Metals Options 2 and 3 sludge filtration systems. The resulting cost curve is presented as Figure 4-4. The O&M upgrade cost equation for the Metals Options 2 and 3 sludge filtration systems is:

$$\mathbf{ln(Y2) = 8.499 + 0.331ln(X) + 0.013(ln(X))^2} \quad \textbf{(4-4)}$$

where:

X = Flow Rate (MGD) of Liquid Stream and

Y2 = O&M Cost (1989 $/YR).

Table 4-3. O&M Upgrade Cost Estimates for Plate and Frame Filtration - Metals Options 2 and 3 (Sludge Stream - Excluding Filter Cake Disposal Costs)

Wastewater Influent Flow (MGD)	Energy	Maintenance	Labor	O&M Cost (1989 $ /YR)
0.000001	30	12	531	574
0.00001	30	12	531	574
0.0001	30	12	531	574
0.001	30	18	1,063	1,113
0.01	30	56	1,606	1,693
0.05	31	180	1,606	1,818
0.10	33	328	1,606	1,968
0.50	45	1,668	1,875	3,589
1.0	61	3,716	2,146	5,924

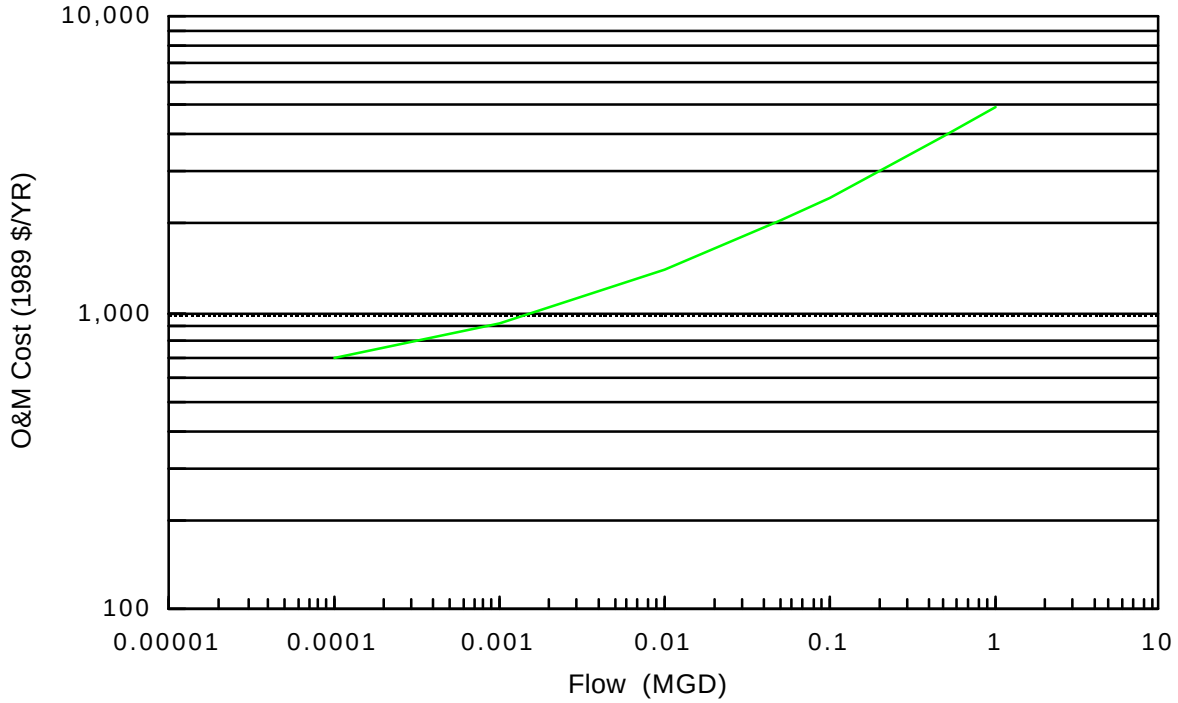

Figure 4-4. Plate and Frame Filtration (Sludge Stream) O&M Upgrade Cost Curve - Metals Options 2 and 3

Operation and Maintenance Costs - Metals Option 4

The operation and maintenance costs for Metals Option 4 consists of labor, chemical usage, electricity, maintenance, taxes, and insurance, and filter cake disposal. The O&M plate and frame sludge filtration costing methodology for Metals Option 4 is very similar to the one discussed previously for Metals Options 2 and 3. The primary differences in the methodologies are the estimation of labor, the inclusion of filter cake disposal, and the O&M upgrade methodology.

EPA approximated the labor requirement for Metals Option 4 plate and frame sludge filtration systems at 2 to 8 hours per day depending on the size of the system. As was the case for Metals Options 2 and 3, no chemicals are used in the plate and frame sludge filtration units for Metals Option 4, and EPA estimated electricity, maintenance and taxes and insurance using the factors listed in Table 1-2. EPA also included filter cake disposal costs at $0.74 per gallon of filter cake. A detailed

discussion of the basis for the filter cake disposal costs is presented in Section 4.2. Table 4-4 presents the itemized O&M estimates for the Metals Option 4 sludge filtration systems. The resulting cost curve is presented as Figure 4-5. The O&M cost equation for the Metals Option 4 sludge filtration systems is:

$$\mathbf{\ln(Y2) = 15.9321 + 1.177\ln(X) + 0.04697(\ln(X))^2} \qquad \mathbf{(4\text{-}5)}$$

where:

X = Flow Rate (MGD) of Liquid Stream and

Y2 = O&M Cost (1989 $/YR).

Table 4-4. O&M Cost Estimates for Plate and Frame Pressure Filtration - Metals Option 4 (Sludge Stream - Including Filter Cake Disposal Costs)

Flow (MGD)	Energy	Maintenance	Taxes & Insurance	Labor	Filter Cake Disposal	Total O&M Cost (1989 $/YR)
0.000001	1,000	404	202	7,800	8	9,414
0.00001	1,000	404	202	7,800	77	9,483
0.0001	1,001	414	209	11,700	770	14,094
0.001	1,005	632	316	11,700	7,696	21,349
0.01	1,010	1,882	941	15,600	76,960	96,393
0.1	1,104	10,935	5,468	19,500	769,600	806,607
0.5	1,520	55,607	27,804	23,400	3,848,000	3,956,331
1.0	2,040	123,876	61,938	31,200	7,696,000	7,915,054

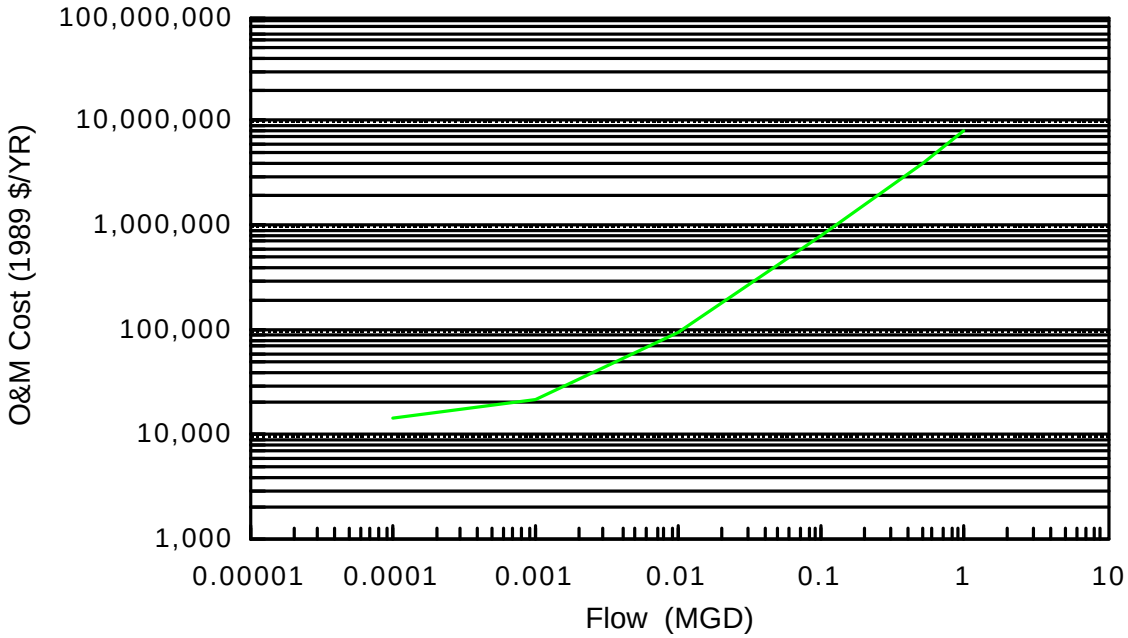

Figure 4-5. Plate and Frame Filtration (Sludge Stream) O&M Cost Curve - Metals Option 4

For facilities which already have a sludge filtration system in-place, EPA included sludge stream filtration O&M upgrade costs. For Metals Option 4, EPA included these O&M upgrade costs for processing the sludge generated from the primary precipitation and clarification steps[2]. These facilities would need to improve pollutant removals from their primary precipitation current performance concentrations to Metals Option 4 (Sample Point-03) concentrations. This sample point represents the effluent from the liquid-solids separation unit following primary chemical precipitation at the Metals Option 4 model facility. Therefore, EPA calculated the percent difference between primary precipitation current performance concentrations and Metals Option 4 (Sample Point 03) concentrations. EPA determined that there was an increase of two percent.

As such, for facilities which currently have sludge filtration systems in place, for Metals

[2] EPA did not include O&M upgrade costs for the sludge generated from the secondary precipitation and clarification step (direct dischargers only).

Option 4, EPA included an O&M cost upgrade of two percent of the total O&M costs (except for taxes and insurance, which are a function of the capital cost).

Table 4-5 presents the itemized O&M upgrade cost estimates for the Metals Option 4 sludge filtration systems. Figure 4-6 presents the resulting cost curve. The O&M upgrade cost equation for the Metals Option 4 sludge filtration systems is:

$$\mathbf{\ln(Y2) = 12.014 + 1.17846\ln(X) + 0.050(\ln(X))^2} \qquad \mathbf{(4\text{-}6)}$$

where:

X = Flow Rate (MGD) of Liquid Stream and

Y2 = O&M Cost (1989 $/YR).

Table 4-5. O&M Upgrade Cost Estimates for Plate and Frame Filtration - Metals Option 4 (Sludge Stream - Including Filter Cake Disposal Costs)

Wastewater Influent Flow (MGD)	Filter Cake Disposal	Energy	Maintenance	Labor	Total O&M Cost (1989 $/YR)
0.000001	1	20	8	156	185
0.00001	2	20	8	156	186
0.0001	15	20	8	234	277
0.001	154	20	13	234	421
0.01	1,539	20	38	312	1,909
0.1	15,392	22	219	390	16,023
0.5	76,960	30	1,112	468	78,570
1.0	153,920	41	2,478	624	157,063

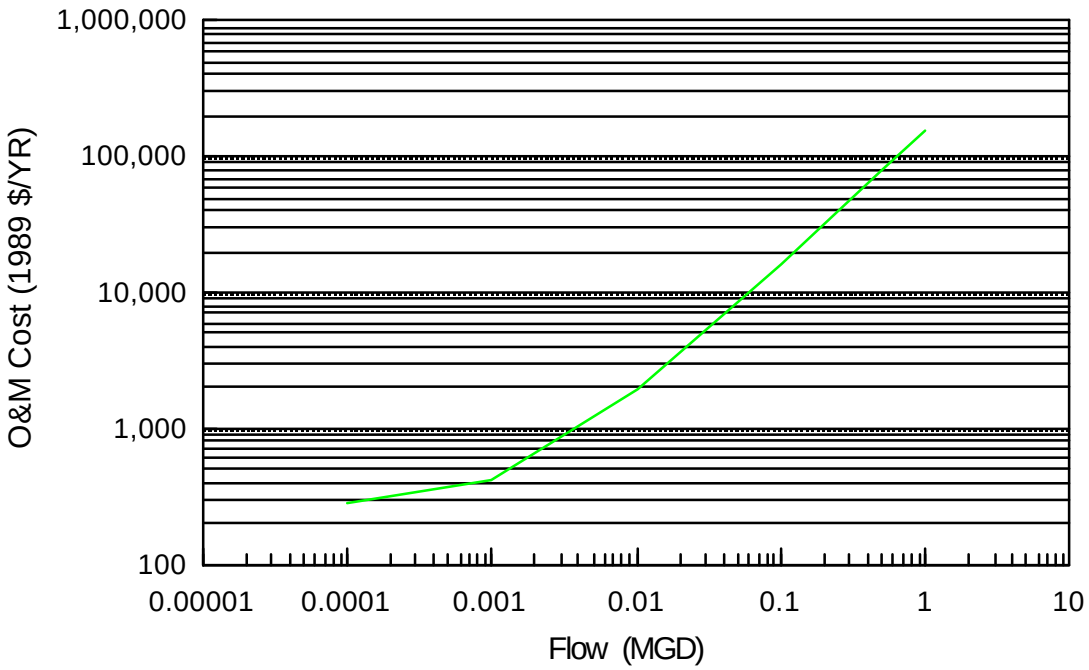

Figure 4-6. Plate and Frame Filtration (Sludge Stream) O&M Upgrade Cost Curve - Metals Option 4

4.2 Filter Cake Disposal

The liquid stream and sludge stream pressure filtration systems presented in Sections 2.2 and 4.1, respectively, generate a filter cake residual. There is an annual O&M cost that is associated with the disposal of this residual. This cost must be added to the pressure filtration equipment O&M costs to arrive at the total O&M costs for pressure filtration operation[3].

To determine the cost of transporting and disposing filter cake to an off-site facility, EPA performed an analysis on a subset of questionnaire respondents in the WTI Questionnaire response database. This subset consists of metals subcategory facilities that are direct and/or indirect

[3] Note that these costs have already been included in the O&M equation for plate and frame sludge filtration for Metals Option 4.

dischargers and that provided information on contract haul and disposal cost to hazardous (Subtitle C) and non-hazardous (Subtitle D) landfills. From this set of responses, EPA tabulated two sets of costs -- those reported for Subtitle C contract haul and disposal and those reported for Subtitle D contract haul and disposal. the reported costs for both the Subtitle C and Subtitle D contract haul/disposal. EPA then edited this information by excluding data that was incomplete or that was not separated by RCRA classification.

EPA used the reported costs information in this data set to determine the median cost for both the Subtitle C and Subtitle D disposal options, and then calculated the weighted average of these median costs. The average was weighted to reflect the ratio of hazardous (67 percent) to nonhazardous (33 percent) waste receipts at these Metals Subcategory facilities. The final disposal cost is $0.74 per gallon of filter cake. Table 4-6 presents this analysis.

EPA calculated a single disposal cost for filter cake using both hazardous and non-hazardous landfilling costs. Certain facilities will incur costs, however, that, in reality, are higher and others will incur costs that, in reality, are lower. Thus, some low revenue metals subcategory facilities that generate non-hazardous sludge may show a higher economic burden than is representative. On the other hand, some low revenue metals subcategory facilities that generate hazardous sludge may show a lower economic burden than is representative. EPA has concluded that in the end, these over- and under estimates will balance out to provide a representative cost across the industry.

EPA additionally estimated an O&M upgrade for filter cake disposal resulting from Metals Options 2 and 3 for facilities that already generate filter cake as part of their operation.

This upgrade is 3 percent of the cost of the O&M upgrade for facilities that do not already generate filter cake as a part of their operation. EPA used 3 percent because this was the same percentage calculated for plate and frame sludge filtration for these same options.

Table 4-6. CWT Metals Subcategory Filter Cake Disposal Costs

CWT QID	Filtercake Quantity (Pounds per Year)	Total Cost (1989 $ per Year)	Unit Cost (1989 $/G Filter Cake)
Subtitle C Landfills			
022	2,632,000	250,000	0.95
072	8,834,801	835,484	0.95
080	6,389,520	711,000	1.11
089	9,456,000	602,471	0.64
100	968,000	125,964	1.30
105	13,230,000	1,164,200	0.88
255	3,030,000	530,250	1.75
257	151,650	12,450	0.82
284	5,850,000	789,000	1.35
288	297,234	36,750	1.24
294	2,628,600	390,000	1.48
449	36,000,000	2,000,000	0.56
MEDIAN			1.03
Subtitle D Landfills			
067	15,393,486	276,160	0.18
072	440,000	24,200	0.55
119	30,410,880	361,000	0.19
132	26,378,000	158,273	0.06
133	36,960,587	780,351	0.21
135	131,451,200	2,768,225	0.21
231	80,000,000	800,000	0.10
294	56,777,760	898,560	0.16
298	2,365,740	18,800	0.08
MEDIAN			0.16
Weighted Average of Subtitle C and D Landfills Median Values			
Weighted Average ($1.03 @ 67% + $0.16 @ 33%)			0.74

Source: WTI Questionnaire Data Base

Note: Pounds = Gallons X 8.34 X Specific Gravity (SG filtercake = 1.2)

Table 4-7 presents the cost estimates for the filter cake disposal O&M and filter cake disposal O&M upgrades for Metals Options 2 and 3 systems. Figures 4-7 and 4-8 present the resulting cost curves. The filter cake disposal O&M cost and O&M upgrade cost equations are presented below as Equations 4-7 and 4-8, respectively.

$$\mathbf{Z = 0.109169 + 7{,}695{,}499.8(X)} \quad \textbf{(4-7)}$$

$$\mathbf{Z = 0.101186 + 230{,}879.8(X)} \quad \textbf{(4-8)}$$

where:

X = Flow Rate (MGD) of Liquid Stream and

Z = Filter Cake Disposal Cost (1989 $/YR).

Table 4-7. Filter Cake Disposal Cost Estimates for Plate and Frame Pressure Filtration Systems - Metals Options 2 and 3

Wastewater Influent Flow (MGD)	Filter Cake Disposal Costs (1989 $/YR)	Filter Cake Upgrade Disposal Costs (1989 $/YR)
0.000001	8	1
0.00001	77	2
0.0001	770	23
0.001	7,696	231
0.01	76,960	2,309
0.05	384,800	11,544
0.10	769,600	23,088
0.50	3,848,000	115,440
1.0	7,696,000	230,880

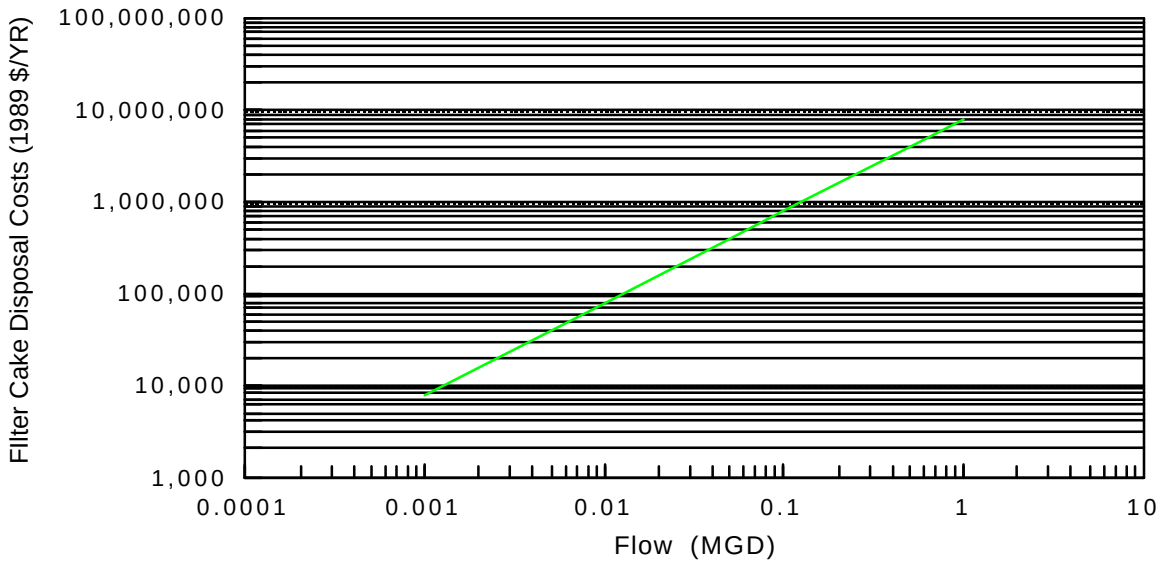

Figure 4-7. Filter Cake Disposal O&M Cost Curve for Plate and Frame Filtration Systems - Metals Options 2 and 3

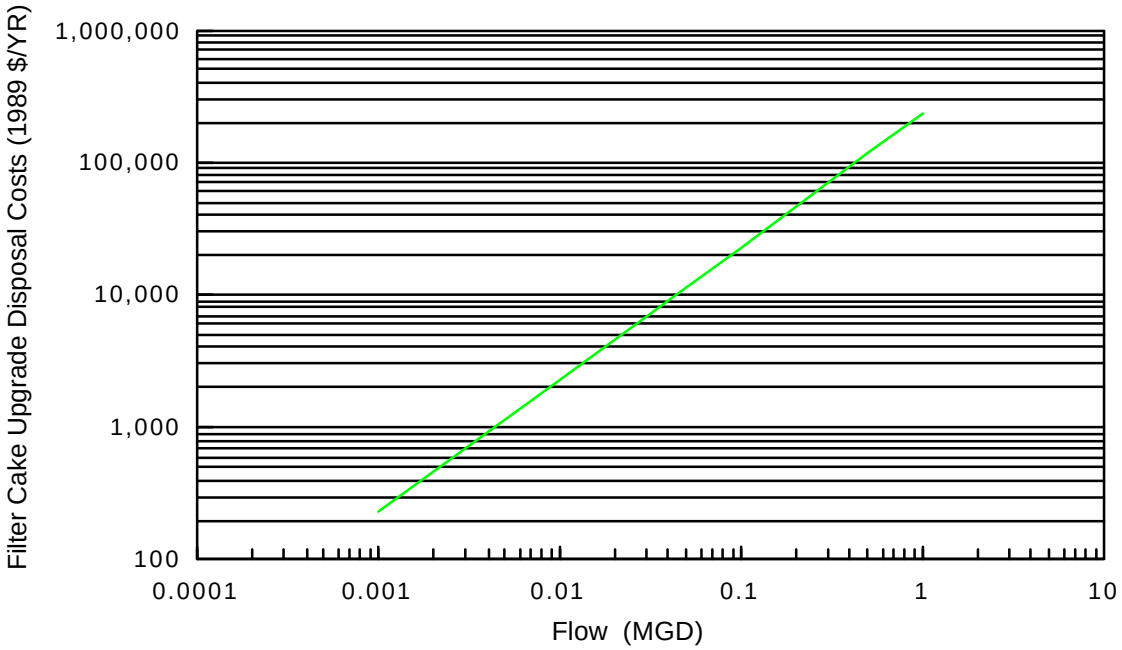

Figure 4-8. Filter Cake Disposal O&M Upgrade Cost Curve for Plate and Frame Filtration Systems - Metals Options 2 and 3